FRAGMENTATION CHARACTERISTICS OF HORIZONTALLY STACKED BOMBS

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INTRODUCTION

The FRAGHAZ Computer Program[1] was developed by the Naval Surface Warfare Center (NSWC/Dahlgren) for the Department of Defense Explosives Safety Board (DDESB). The primary purpose of the program was to provide a means for estimating the fragment hazards to personnel from the inadvertent detonation of stacks of stored munitions.

The Computer Program is primarily a Monte-Carlo type incorporating the capability of statistically handling a number of uncertain variables. The model relies on small-scale fragmentation arena tests to provide the fragment data for full-scale ammo stack investigations. Each fragment recovered from the test, greater than a specified minimum weight, forms the basis for a trajectory which is calculated in its entirety using a fourth order Runge-Kutta routine.

The intersection of the fragment trajectory with a hazard volume (a pie-shaped volume with an angular width, usually 10 degrees or less, and a height equal to the target height) provides the means for calculating the fragment hazard to the target in terms of density and probability of hit. Since we calculate the entire trajectory, we know both the static and dynamic characteristics of the fragment at all ranges where the trajectory intersects the hazard volume. The target is assumed to be randomly located within the hazard volume and the hazard volume ranges are normally divided into 100 feet increments.

A number of fragments is associated with each trajectory to represent the number expected from a full-scale stack. The results for the intersection of each trajectory with the hazard volume are recorded and accumulated. After all fragments trajectories are run, the procedure is repeated (replicated) about 60 times with different values for the uncertain variables. This is normal for a Monte-Carlo procedure. Statistical data are then obtained from the results of the 60 replications as a function of range (usually in 100 foot increments).

The FRAGHAZ program includes the effects of ground ricochet, altitude (air density and Mach number), complete drag curves, wind, target impact angle, and varying fragment velocity.

Correspondence of the predictive number of fragments versus range and actual pickup tests in the desert has been checked for two stacked munition cases. The comparison was good and is contained in the FRAGHAZ Computer Program report.[2]

MK 82 (500 LB) BOMB
HORIZONTALLY STACKED MUNITIONS

For projectiles and bombs, there are basically two types of storage: (1) vertical storage (155mm projectiles) and (2) horizontal storage (MK 82 bombs). These two types of storage are depicted in Figure 1 - horizontal storage on the top left and vertical storage on the top right. For both types of storage, a hazard elevation sector is shown. The sides of the elevation sector form a

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[1] Quantity-Distance Fragment Hazard Computer Program (FRAGHAZ), NSWC TR 87-59, Frank McCleskey, Feb 1988, Unclassified.

[2] Ibid

dihedral angle; the intersection of the dihedral planes form a vertical line on the face of the stack. All fragments are assumed to begin their trajectories along this vertical line which is acceptable so long as the width of the stack is no more than 200 feet or so. All fragment trajectories contained within the dihedral angle will ultimately intersect the hazard volume whose angular width is equal to the dihedral angle.

The most hazardous fragmentation is contained within the hazard elevation sector. Between adjacent projectiles or bombs, interaction areas (jets) are formed which have higher velocities, higher fragment densities, and higher fragment weights than those produced by a single projectile or bomb detonation. In order to obtain the approximate fragment characteristics of the hazard elevation sector, the projectiles or bombs are rotated 90 degrees and tested in a horizontal fragmentation test arena as shown in the left bottom and right bottom of Figure 1. The hazard elevation sectors are shown as dotted lines in the bottom views of Figure 1. Note the relation of elevation angles (EL) and polar angles (PA) in the Figure.

The fragmentation characteristics from the vertically stored munitions are fundamentally different from the horizontally stored munitions. On the right top of Figure 1, the top of the vertically stored stack does not appear to produce any significant down range fragmentation. Conversely, the horizontally stored munitions have both top and side interaction areas (jets) when the stack is detonated simultaneously or nearly so. Depending on the initiation point, the top interaction areas will produce downrange fragmentation. Fragmentation from the top interaction areas will normally go to shorter ranges than the fragmentation from the side of the stack. Since the hazard elevation sector (Figure 1) is like an orange slice coming to a point at Elevation Angle = 90 degrees (Polar Angle = 0 degrees), a smaller portion of the fragmentation from the top interaction areas will be used in the FRAGHAZ Program.

Fragmentation from vertically stored munitions will consist of only one zone while fragmentation from horizontally stored munitions will consist of four zones as shown in Figure 2. Here the bottom-middle bomb is assumed to be the initiation point and the remainder of the bombs are initiated by sympathetic detonation. Lines drawn from the center of the initiator bomb can be drawn to show approximately the four zones of downrange fragmentation from a single pallet (6 bombs) of MK 82 bombs. The fragmentation in zones 1 and 3 comes from 180 degrees of the bomb cases. This is only approximate since the dynamics of the interaction areas (jets) are not clearly understood. Zones 2 and 4 are taken to be normal fragmentation areas as you would experience with a single bomb.

Looking at fragment numbers or fragment weight does not clearly outline the four zones. Looking at initial velocity versus polar angle, Figure 3, does show the zone separations. The actual velocities from a single test, shown in Figure 3, still leave some questions, but the existence of zones appears to be clearly defined. Note that the initial velocities of fragments in the interaction areas (zones 1 and 3) are approximately 40 percent higher than the initial velocities of a single round beam spray. The initial velocities in the normal areas (zones 2 and 4) are somewhat lower than the velocities obtained from a single bomb. This is not clearly understood.

It is interesting to note the effect on a fragment's range produced by changes in its initial velocity, average presented area to mass ratio, or drag coefficient. Range is dependent on initial kinetic energy, a function of V^2, but the retarding effects of air drag are also a function of V^2. The two tend to offset one another with the initial kinetic energy dominant, but not as much as one might suspect. As shown in Table 1, increasing initial velocity threefold, with other variables held constant at any values, produces only a 30 percent increase in range. For example, if the range at an elevation angle of 20 degrees was 1000 feet for an initial velocity of 2000 ft/sec, it would only

increase to 1300 feet when the initial velocity was increased to 6000 ft/sec. On the other hand, if the drag coefficient or $\bar{A}/m$ was decreased by a factor of 3, the range would increase by 120 and 150 percent, respectively. The range increases are 4 and 5 times greater than those obtained with a similar factor of 3 increase in initial velocity. For the MK 82 bomb, where we have only a 40 percent increase in initial velocity for an interaction area (jet) over a single bomb, we would see only a 5 percent increase in range. Apparently it is fragment density rather than initial velocity which controls hazard range. Hazard range depends not only on fragment range but on the hazard density being greater than one fragment per 600 square feet (hazard probability of hit being greater than .01 with a constant presented area of the personnel target equal to 6 square feet). The density of fragments in the interaction area (jet) for the MK 82 bomb is at least twice that for the beam spray of a single bomb.

In all mass detonation tests to date the projectiles or bombs have been in contact with one another. Separation (maybe by only inches) of the projectiles and bombs in the stack would ultimately prevent the formation of interaction areas (jets) and thus significantly reduce hazard range due primarily to reduced fragment density. Future tests are worth considering since hazard ranges in some cases might be reduced by as much as 500 or 1000 feet.

FIGURE 1

FRAGHAZ STORAGE AND TEST ATTITUDES

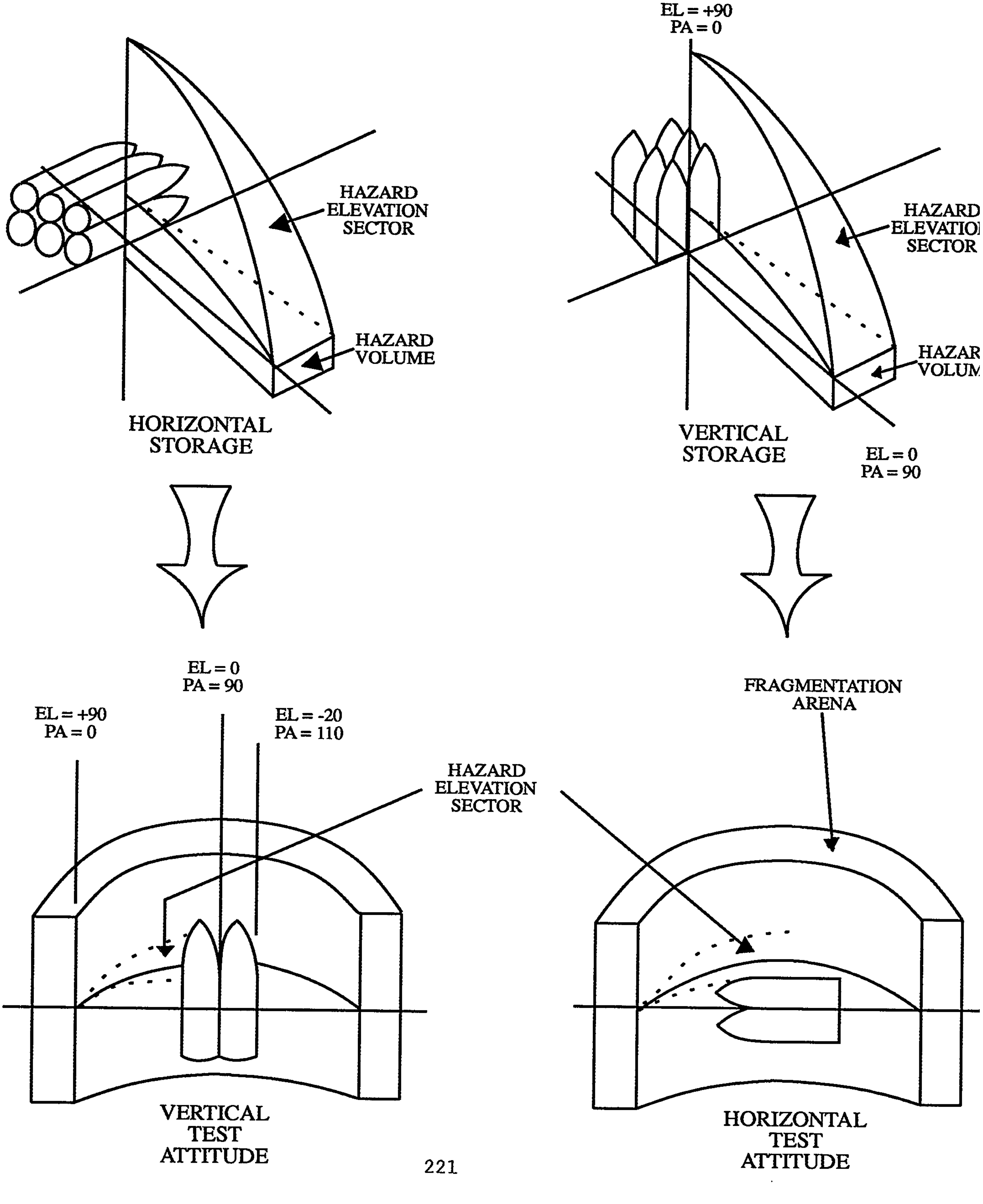


FIGURE 2

MK 82 BOMB PALLET FRAGMENTATION MASS DETONATING

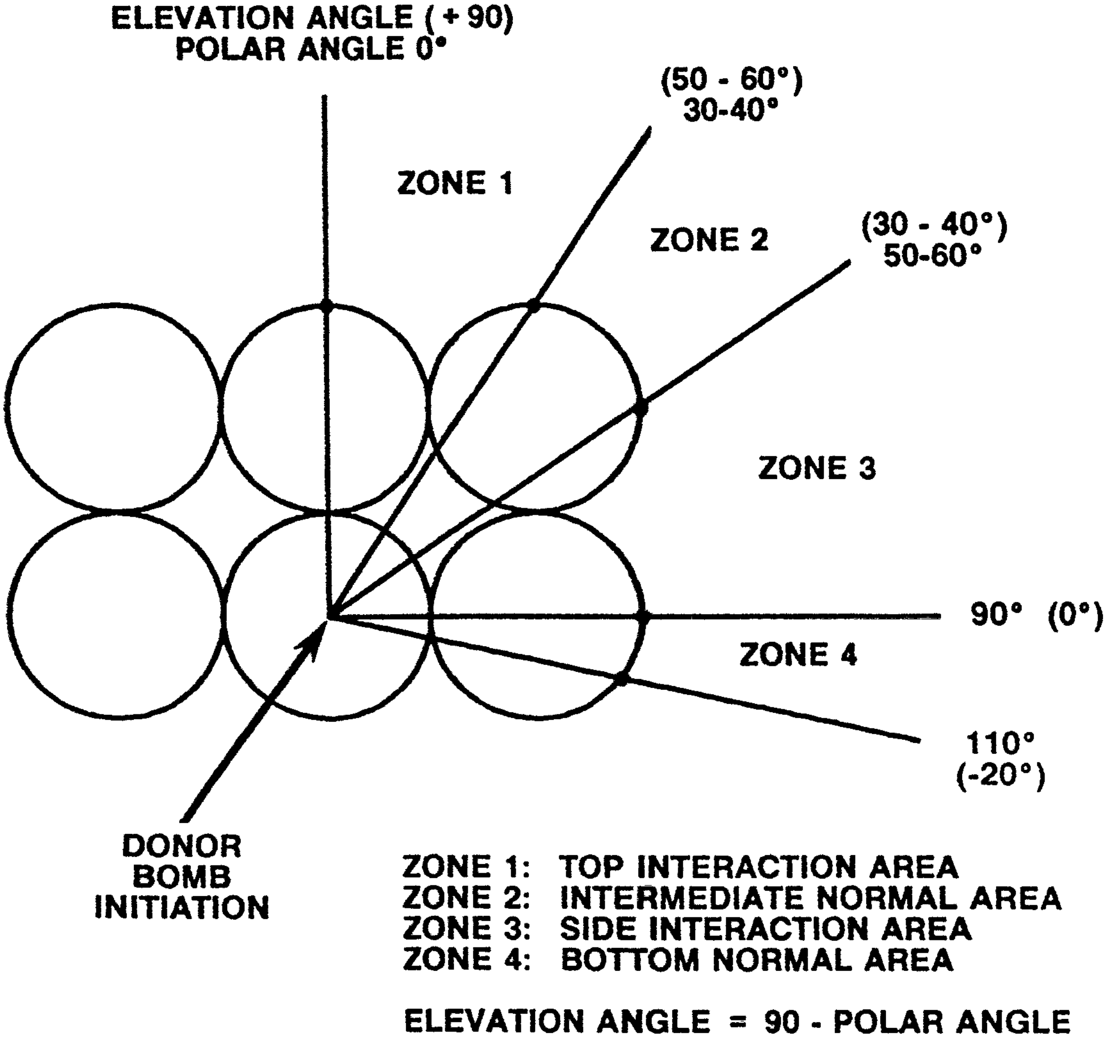
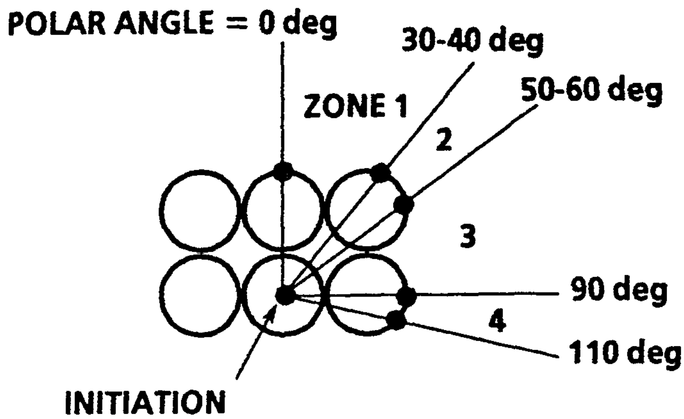


FIGURE 3

MK 82 (500 lb) BOMBS
INITIAL VELOCITIES - MASS DETONATING



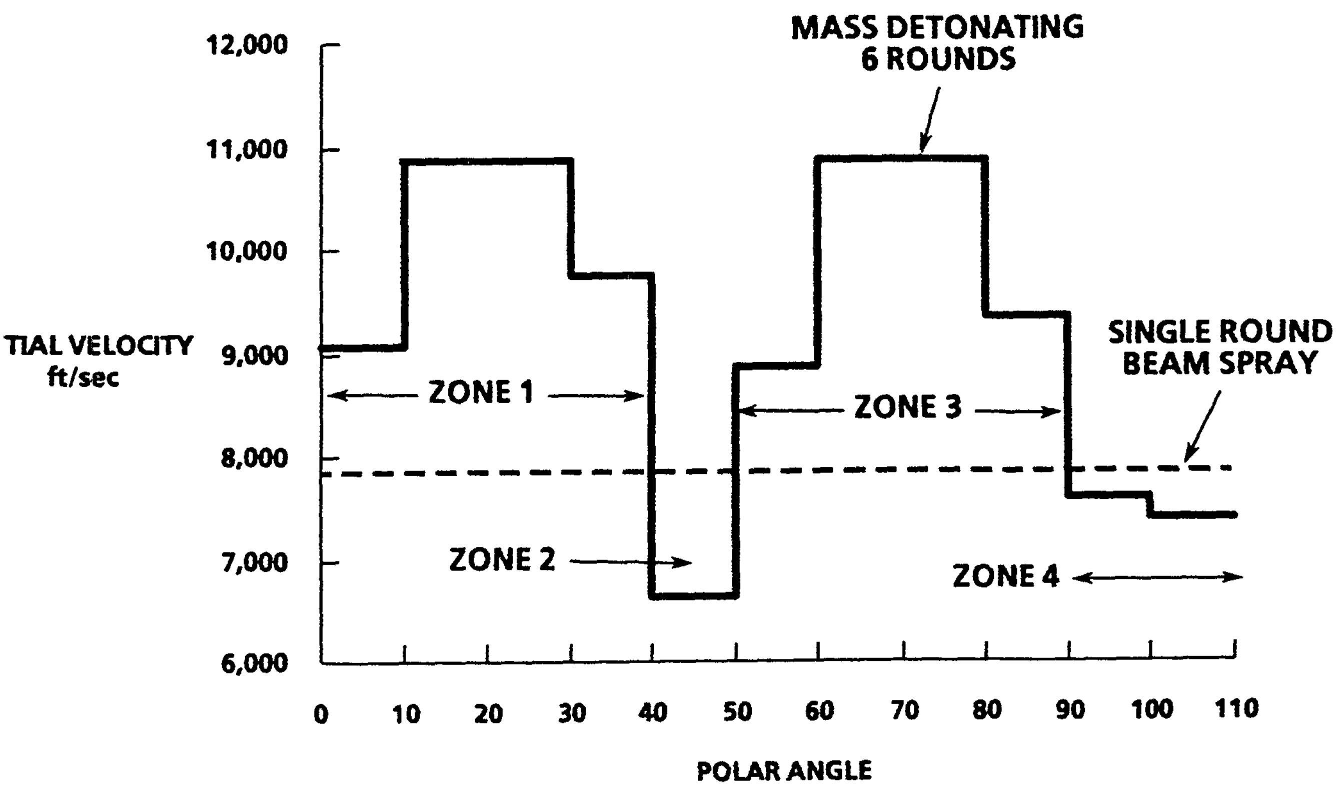


TABLE 1

PARAMETER SENSITIVITY

SEA LEVEL NO WIND ELEVATION = 20 deg

PARAMETER	VALUE CHANGE	APPROXIMATE RANGE INCREASE (PERCENT)
V_O	3500 to 10500	30
$C_D(M \approx .1)$	1.8 to 0.6	120
$\bar{A}/M$	18 to 6	150

V_O = INITIAL VELOCITY (ft/sec)

$C_D (M \approx .1)$ = DRAG COEFFICIENT AT MACH NO. $\approx$ .1

$\bar{A}/M$ = AVERAGE PRESENTED AREA TO MASS RATIO (in.^{2}/lb)

$$a = \frac{\rho C_D \bar{A} V^2}{2 M}$$

NEGATIVE DRAG ACCELERATION